Unit 4.1 - Cell Respiration and Photosynthesis

<u>Syllabus Statements</u> *(HL material in italics)*

- C1.2.1—ATP as the molecule that distributes energy within cells"Include the full name of ATP (adenosine triphosphate) and that it is a nucleotide. Students should appreciate the properties of ATP that make it suitable for use as the energy currency within cells."
- C1.2.2—Life processes within cells that ATP supplies with energy "Include active transport across membranes, synthesis of macromolecules (anabolism), movement of the whole cell or cell components such as chromosomes."
- C1.2.3—Energy transfers during interconversions between ATP and ADP - "Students should know that energy is released by hydrolysis of ATP (adenosine triphosphate) to ADP (adenosine diphosphate) and phosphate, but energy is required to synthesize ATP from ADP and phosphate. Students are not required to know the quantity of energy in kilojoules, but students should appreciate that it is sufficient for many tasks in the cell."
- C1.2.4—Cell respiration as a system for producing ATP within the cell using energy released from carbon
- compounds - "Students should appreciate that glucose and fatty acids are the princial substrates for cell respiration but that a wide range of carbon/organic compounds can be used. Students should be able to distinguish between the processes of cell respiration and gas exchange."
- C1.2.5—Differences between anaerobic and aerobic cell respiration in humans - "Include which respiratory substrates can be used, whether oxygen is required, relative yields of ATP, types of waste product and where the reactions occur in a cell. Students should be able to write simple word equations for both types of respiration, with glucose as the substrate. Students should appreciate that mitochondria are required for aerobic, but not anaerobic, respiration.
- C1.2.6—Variables affecting the rate of cell respiration - Students should make measurements allowing for the determination of the rate of cell respiration. Students should also be able to calculate the rate of cellular respiration from raw data that they have generate experimentally or from secondary data.
- *C1.2.7 (HL)—Role of NAD as a carrier of hydrogen and oxidation by removal of hydrogen during cell respiration -"Students should understand that oxidation is a process of electron loss, so when hydrogen with an electron is removed from a substrate (dehydrogenation) the substrate has been oxidized. They should appreciate that redox reactions involve both oxidation and reduction, and that NAD is reduced when it accepts hydrogen.*
- *C1.2.8 (HL)—Conversion of glucose to pyruvate by stepwise reactions in glycolysis with a net yield of ATP and reduced NAD" - "Include phosphorylation, lysis, oxidation and ATP formation. Students are not required to know the names of the intermediates, but students should know that each step in the pathway is catalysed by a different enzyme."*
- *C1.2.9 (HL)—Conversion of pyruvate to lactate as a means of regenerating NAD in anaerobic cell respiration - "Regeneration of NAD allows glycolysis to continue, with a net yield of two ATP molecules per molecule of glucose."*
- *C1.2.10 (HL)—Anaerobic cell respiration in yeast and its use in brewing and baking - "Students should understand that the pathways of anaerobic respiration are the same in humans and yeasts apart from the regeneration of NAD using pyruvate and therefore the final products."*
- *C1.2.11 (HL)—Oxidation and decarboxylation of pyruvate as a link reaction in aerobic cell respiration - "Students should understand that lipids and carbohydrates are metabolized to form acetyl groups (2C),*
  which are transferred by coenzyme A to the Krebs cycle."
- *"C1.2.12 (HL)—Oxidation and decarboxylation of acetyl groups in the Krebs cycle with a yield of ATP and reduced NAD - "Students are required to name only the intermediates citrate (6C) and oxaloacetate (4C). Students should appreciate that citrate is produced by transfer of an acetyl group to oxaloacetate and that oxaloacetate is regenerated by the reactions of the Krebs cycle, including four oxidations and two decarboxylations. They should also appreciate that the oxidations are dehydrogenation reactions."*
- *C1.2.13 (HL)—Transfer of energy by reduced NAD to the electron transport chain in the mitochondrion - "Energy is transferred when a pair of electrons is passed to the first carrier in the chain, converting reduced NAD back to NAD. Students should understand that reduced NAD comes from glycolysis, the link reaction and the Krebs cycle."*
- *C1.2.14 (HL)—Generation of a proton gradient by flow of electrons along the electron transport chain - Students are not required to know the names of protein complexes.*
- *"C1.2.15 (HL)—Chemiosmosis and the synthesis of ATP in the mitochondrion" - "Students should understand how ATP synthase couples release of energy from the proton gradient with phosphorylation of ADP."*
- *C1.2.16 (HL)—Role of oxygen as terminal electron acceptor in aerobic cell respiration - "Oxygen accepts electrons from the electron transport chain and protons from the matrix of the mitochondrion, producing metabolic water and allowing continued flow of electrons along the chain."*
- *C.1.2.17 (HL)—Differences between lipids and carbohydrates as respiratory substrates - "Include the higher yield of energy per gram of lipids, due to less oxygen and more oxidizable hydrogen and carbon. Also include glycolysis and anaerobic respiration occurring only if carbohydrate is the substrate, with 2C acetyl groups from the breakdown of fatty acids entering the pathway via acetyl-CoA (acetyl coenzyme A)."*
- "C1.3.1—Transformation of light energy to chemical energy when carbon compounds are produced in photosynthesis" - This energy transformation supplies most of the chemical energy needed for life processes in ecosystems.
- C1.3.2—Conversion of carbon dioxide to glucose photosynthesis using hydrogen obtained by splitting water" - Students should be able to write a simple word equation for photosynthesis, with glucose as the product.
- C1.3.3—Oxygen as a by-product of photosynthesis in plants, algae and cyanobacteria - "Students should know the simple word equation for photosynthesis. They should know that the oxygen produced by photosynthesis comes from the splitting of water."

- C1.3.4—Separation and identification of photosynthetic pigments by chromatography - "Students should be able to calculate Rf values from the results of chromatographic separation of photosynthetic pigments and identify them by colour and by values. Thin-layer chromatography or paper chromatography can be used."
- C1.3.5—Absorption of specific wavelengths of light by photosynthetic pigments- "Include excitation of electrons within a pigment molecule, transformation of light energy to chemical energy and the reason that only some wavelengths are absorbed. Students should be familiar with
absorption spectra. Include both wavelengths and colours of light in the horizontal axis of absorption spectra."
- C1.3.6—Similarities and differences of absorption and action spectra Students should be able to determine rates of photosynthesis from data for oxygen production and carbon dioxide consumption for varying wavelengths. They should also be able to plot this data to make an action spectrum.
- "C1.3.7—Techniques for varying concentrations of carbon dioxide, light intensity or temperature experimentally to investigate the effects of limiting factors on the rate of photosynthesis"
Students should be able to suggest hypotheses for the effects of these limiting factors and explore protocols based upon their understanding of photosynthesis, and test these by experimentation.
- C1.3.8—Carbon dioxide - Include enclosed greenhouse experiments and free-air carbon dioxide enrichment experiments (FACE).
- *C1.3.9 (HL)—Photosystems as arrays of pigment molecules that can generate and emit excited electrons -"Students should know that photosystems are always located in membranes and that they occur in*
cyanobacteria and in the chloroplasts of photosynthetic eukaryotes. Photosystems should be described as molecular arrays of chlorophyll and accessory pigments with a special chlorophyll as the reaction centre from which an excited electron is emitted."
- *C1.3.10 (HL)—Advantages of the structured array of different types of pigment molecules in a photosystem - "Students should appreciate that a single molecule of chlorophyll or any other pigment would not be able to perform any part of photosynthesis."*
- *C1.3.11(HL)—Generation of oxygen by the photolysis of water in photosystem II - "Emphasize that the protons and electrons generated by photolysis are used in photosynthesis but oxygen is a waste product. The advent of oxygen generation by photolysis had immense consequences for living organisms and geological processes on Earth."*
- *C1.3.12(HL)—ATP production by chemiosmosis in thylakoids - "Include the proton gradient, ATP synthase, proton pumping by the chain of electron carriers and also the electrons sourced from photosystem I in cyclic photophosphorylation or photosystem II in non-cyclic photophosphorylation."*
- *C1.3.13 (HL)—Reduction of NADP by photosystem I -"Students should appreciate that NADP is reduced by accepting two electrons that have come from photosystem I. It also accepts a hydrogen ion that has come from the stroma. The paired terms - "NADP and reduced NADP" or "NADP+ and NADPH" should be paired consistently."*
- *C1.3.14 (HL)—Thylakoids as systems for performing the light-dependent reactions of photosynthesis- "Students should appreciate where photolysis of water, synthesis of ATP by chemiosmosis and reduction of NADP occur in a thylakoid."*
- *C1.3.15 (HL)—Carbon fixation by Rubisco - "Students should know the names of the substrates RuBP and CO2 and the product glycerate 3-phosphate. They should also know that Rubisco is the most abundant enzyme on Earth and that high concentrations of it are needed in the stroma of chloroplasts because it works relatively slowly and is not effective in low carbon dioxide concentrations."*
- *C1.3.16 (HL)—Synthesis of triose phosphate using reduced NADP and ATP - Reduced NADP supplies hydrogen for reducing NADP, and ATP supplies the necessary energy.*
- *C1.3.17 (HL) —Regeneration of RuBP in the Calvin cycle using ATP "Students are not required to know details of the individual reactions, but students should understand that five molecules of triose phosphate are converted to three molecules of RuBP, allowing the Calvin cycle to continue. If glucose is the product of photosynthesis, five-sixths of all the triose phosphate produced must be converted back to RuBP."*
- *"C1.3.18 (HL)—Synthesis of carbohydrates, amino acids and other carbon compounds using the products of the Calvin cycle and mineral nutrients"- "Students are not required to know details of metabolic pathways, but students should understand that all of the carbon in compounds in photosynthesizing organisms is fixed in the Calvin cycle and that carbon compounds other than glucose are made by metabolic pathways that can be traced back to an intermediate in the cycle."*
- *C1.3.19 (HL)—Interdependence of the light-dependent and light-independent reactions "Students should understand how a lack of light stops light-independent reactions and how a lack of CO2 prevents photosystem II from functioning."*
- *B2.2.4 (HL)—Adaptations of the mitochondrion for production of ATP by aerobic cell respiration - "Include these adaptations: a double membrane with a small volume of intermembrane space, large surface area of cristae and compartmentalization of enzymes and substrates of the Krebs cycle in the matrix."*
- *B2.2.5 (HL)—Adaptations of the chloroplast for photosynthesis -"Include these adaptations: the large surface area of thylakoid membranes with photosystems, small volumes of fluid inside thylakoids, and compartmentalization of enzymes and substrates of the Calvin cycle in the stroma."*